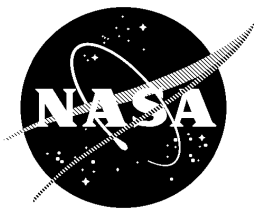


New Millennium Program Earth Orbiter-1 (EO-1) Spacecraft Level II Requirements



National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

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Abbreviations and Acronyms

Section 1. Introduction

This document contains the New Millennium Program (NMP) Earth Orbiter-1 (EO-1) Spacecraft Level II requirements. The EO-1 Spacecraft Level II requirements specify and define requirements at the spacecraft subsystem level. These requirements address spacecraft subsystem level functional and performance specifications as well as interface requirements.

The EO-1 mission requirement definition is accomplished in three levels. The Level I requirements define the EO-1 mission objectives and products. The Level II requirements identify and allocate appropriate requirements to mission segments (Technology, Spacecraft, Ground Segment). The Level II requirements are top-level requirements for each mission segment. The Level III requirements are the lowest level requirements for the mission. The Level III requirements are directly implemented at the hardware and software levels. The Level III requirements are traced to Level II and then to Level I. All Level III requirements have either parent requirements in Level II and/or Level I, or have justification for their orphan status.

Section 2. Requirement Organization

Requirements are organized and identified by Requirement ID, Requirement Type, Requirement Title, and Requirement Statement. The Requirement ID is a numbering system where each requirement is assigned a unique number. This number is used in tracing a requirement from parent to child and vice versa. The Requirement Type is an indicator for the type of requirement. A detailed description of the Requirement Types is provided in the Section 3. The Requirement Title is a title for the requirement. The Requirement Statement provides the required action or activity. There is only one required action or activity per Requirement Statement.

The Level II requirements for the Spacecraft segment of EO-1 are given in Appendix A.

Section 3. Requirement Type Definitions

The requirement types are defined below.

H (Hierarchical) Requirement—A requirement that is not directly verifiable but provides structure to a set of requirements. A hierarchical requirement must be verified “through validation.” This means that the child requirements must be validated to define the success of the parent, and the child requirements must be verifiable.

NOTE: Child requirements may themselves be hierarchical.

FC (Functional Category)—A hierarchical requirement that is the parent of a set of child requirements. Generally the functional category may be viewed as a container of a set of requirements that are “alike” in some manner, such as

- a. Have similar functionality
- b. Have the same functionality applied to different elements
- c. Are verified as a group

F (Functional) Requirement—A requirement that is a child requirement to a functional category. A functional requirement is the parent requirement to performance requirements. Functional requirements specify functions of the system, subsystem, instrument, or component. Functional requirements must be verifiable by test, analysis, or inspection.

P (Performance) Requirement—A requirement that is a child requirement to a functional requirement. The performance requirements are directly verifiable, and each performance level is verified. The performance requirements specify discrete performance levels of the system, subsystem, instrument, and/or component. The verification methods for performance requirements are test, analysis, and/or inspection.

Section 4. Requirement Verification

The requirements shall be verified using methods accepted by the EO-1 mission management. The acceptable verification methods include testing, analyses, and/or inspection. Positive verification for each requirement shall be provided. A requirement shall be verified either directly or indirectly. An example of an indirect verification would be such that a Level I requirement is traced to Level II and then to Level III, where a direct verification of the Level III requirement is accomplished. In this case, the Level I and II requirements are verified indirectly, and the Level III requirement is verified directly. This is an acceptable verification approach.

Section 5. Requirements Verification Matrix

The requirements verification matrix shall be developed. The matrix shall identify the requirement, verification method, verification acceptable criteria, verification results, and date of verification.

Section 6. EO-1 System Validation

The requirements verification matrix, along with requirements tracing to either parent or child, shall be the basis for the EO-1 system validation.

Appendix A. NMP EO-1 Spacecraft Level II Requirements

Requirement ID	Requirement Type	Requirement Title	Requirement Statement
01	H	NMP/EO-1 Spacecraft Requirements: Level II	This document defines Level II requirements for the NMP EO-1 spacecraft. The spacecraft shall provide all resources necessary to accommodate, operate, and validate the EO-1 technologies.
01.01	H	General	The spacecraft shall adhere to the requirements in this section.
01.01.00.01	F	Mission Life	Shall be designed to support mission life of 1 year nominally and 18 months for expendables.
01.01.00.01	F	Environment	All hardware and software shall adhere to EO-1 environmental requirements. (Reference: document SAI-SPEC-158)
01.01.00.02	F	Contamination Control	The spacecraft and observatory materials, processes, and facilities shall exercise sufficient contamination control to facilitate validation of the technologies.
01.01.00.02.01	P	Radiation Environment-TID	All component used in the construction of the spacecraft shall be capable of performing to these requirements after being subjected to 15 Krads of Total Ionizing Dose on-orbit.
01.01.00.02.02	P	Radiation Environment-SEE	Parts used shall be immune to latchup. Parts that exhibit any single event effects lower than 35 MEV shall not degrade mission performance.
01.01.00.03	F	Charging Prevention	The observatory design shall prevent surface charging/discharging effects capable of damaging observatory components.
01.01.00.04	F	Mission Assurance	All hardware and software shall adhere to EO-1 mission assurance requirements.
01.01.00.05	F	Verification	Shall provide adequate visibility to accommodate effective subsystem and system functional and performance verification at all stages of development.
01.02	H	Attitude Control System (ACS)	The ACS shall provide three-axis stabilization.
01.02.01	FC	Orbit Determination and Knowledge	The spacecraft shall provide sufficient orbit determination to support the driving technology, with the requirements of the others falling within those limits.
01.02.01.01	F	Ground Station Communication	Orbit determination shall provide sufficient knowledge to support communication with ground stations.
01.02.01.02	F	Image Taking	Orbit determination shall provide sufficient knowledge to acquire (real time) and postprocess images with respect to the Earth and Landsat 7.

Requirement ID	Requirement Type	Requirement Title	Requirement Statement
01.02.01.02.01	P	Ground Track	Shall have sufficient precision to maintain ± 3 km (cross-track) of the Landsat 7 ground track.
01.02.01.02.02	P	Real Time	Shall provide sufficient knowledge to perform to requirements of the WIS Spectral Purity paper. [Reference: Litton AM149-0042(155)]
01.02.01.02.03	P	Post-Processing	Shall provide sufficient knowledge to perform to requirements of the WIS Spectral Purity paper. [Reference: Litton AM149-0042(155)]
01.02.01.02.04	P	Landsat 7 Co-Flying	
01.02.01.03	F	Ground-Based Formation Flying	Shall provide sufficient knowledge to allow ground-based formation flying with Landsat 7.
01.02.01.04	F	Enhanced Formation Flying	Shall be capable of providing sufficient knowledge to perform enhanced formation flying.
01.02.02	FC	Orbit Control	Shall provide capability for orbit control.
01.02.02.01	F	Enhanced Formation Flying	Orbit control shall provide sufficient capability to support enhanced formation flying.
01.02.02.02	F	Pointing Knowledge	Shall provide sufficient pointing knowledge for orbit maintenance.
01.02.02.03	F	Ground Track	Shall provide sufficient precision to maintain ± 3 km of the Landsat 7 ground track.
01.02.02.04	F	Equatorial Crossing	Nominal descending equatorial crossing time shall be 1 minute later than Landsat.
01.02.02.05	F	Delta-V Maneuvers	Shall provide the capability for trajectory correction and orbit maintenance.
01.02.03	FC	Attitude Determination and Control	Attitude determination and control shall provide sufficient knowledge to support the mission.
01.02.03.01	F	Technology Validation	Shall provide sufficient knowledge to support validation of the technologies (WIS is most stringent).
01.02.03.02	F	Attitude Telemetry	Telemetry shall be sufficient for ground verification and image processing.
01.02.03.03	F	WIS Validation	Shall provide sufficient control to validate the WIS.
01.02.03.03.01	P	90% Area Rule	Shall implement 90% area rule to 2 sigma. [Reference: Litton AM149-0042(155)]
01.02.03.04	F	Pointing Vector Offset	Shall allow for commanded offset of the pointing vector to allow for misalignment of the ALI boresight to the nadir deck.
01.02.03.04.01	P	Offset Amount	Offset shall be up to $\pm 0.5^\circ$ in any axis.
01.02.03.05	F	Cross-Track	Shall allow for commanded cross-track pointing (about the roll axis).
01.02.03.05.01	P	Cross-Track Pointing	Shall allow up to $\pm 6.5^\circ$ from nadir vector.
01.02.03.05.02	P	Accuracy	Accuracy shall be TBD (derived from 90% rule).
01.02.03.06	F	Solar Calibration	Shall provide capability to perform slew-and-hold or slew-and-scan calibration scenario.

Requirement ID	Requirement Type	Requirement Title	Requirement Statement
01.02.03.06.01	P	Accuracy	Accuracy shall be within 0.25°, 3 sigma, per axis.
01.02.03.07	F	Lunar Calibration	Shall provide capability to perform slew-and-hold or slew-and-scan calibration scenario.
01.02.03.07.01	P	Accuracy	Accuracy shall be within 0.25°, 3 sigma, per axis.
01.02.03.08	F	Deep-Space Calibration	Shall provide capability to perform slew-and-hold or slew-and-scan calibration scenario.
01.02.03.08.01	P	Accuracy	Accuracy shall be within 0.25°, 3 sigma, per axis.
01.02.03.09	F	XPAA Pointing	Shall provide capability to point XPAA to a ground station autonomously.
01.02.03.09.01	P	Ground Station Pointing Accuracy	Pointing information shall be supplied to the XPAA to an accuracy of 1° during transmission only.
01.02.03.09.02	P	Pointing Rate	Pointing command rate shall support a 2-Hz antenna beam position update rate.
01.02.03.10	F	Nadir Pointing	Shall be capable of maintaining a nadir-pointing attitude indefinitely during normal operations.
01.02.03.11	F	Safe Pointing	Shall be capable of maintaining a power-positive and thermally safe solar-pointing inertial hold attitude indefinitely.
01.03	H	Power System	The power system shall provide adequate power to spacecraft and technologies to perform required observations.
01.03.00.01	F	Total Power	Shall provide sufficient power to support the mission in all operational modes.
01.03.00.02	F	Energy Storage	Shall provide sufficient energy storage to support the mission.
01.03.00.03	F	Distribution	Shall provide power distribution within the EO-1 observatory.
01.03.00.04	F	Capacity	The power system shall have sufficient capacity to support all phases of the mission.
01.03.00.05	F	ALI Operation	The ALI FPE shall operate a maximum of 10 minutes per daylight period of each orbit, not exceeding four times per 24-hour period.
01.03.00.06	F	Science Data Downlink (WARP Ops)	Shall provide sufficient capacity to support downlinking of a full WARP recorder twice per 24-hour period.
01.04	H	Electrical System	The electrical system shall provide services to all components per EO-1 electrical specifications. [Reference: Litton AM-149-0020(155)]
01.05	H	RF Communication System	The RF communication system comprises both an X-band and S-band system to support all phases of the mission.
01.05.01	FC	S-Band Communications	The S-band communications system shall provide command uplink, housekeeping telemetry, and tracking (two-way doppler and angle), and science telemetry in a contingency mode only.

Requirement ID	Requirement Type	Requirement Title	Requirement Statement
01.05.01.01	F	Antennae	Shall provide omni-directional coverage for S-band communication.
01.05.01.01.01	P	Antenna Coverage	Shall provide 80% spherical coverage.
01.05.01.02	F	Ground Station Compatibility	Shall be capable of communication with Wallops Flight Facility-managed ground stations.
01.05.01.03	F	Uplink	S-band command uplink shall be sufficient to validate technologies and operate spacecraft.
01.05.01.03.01	P	Uplink Rate	Uplink rate shall be 2 Kbps.
01.05.01.04	F	Housekeeping Downlink	S-band shall be used for the downlink of housekeeping telemetry.
01.05.01.05	F	Science Telemetry	S-band shall be capable of supporting up to 1 Mbps for the downlink of science telemetry in a contingency mode.
01.05.01.06	F	Coherent Communication/ Ranging	S-band shall be capable of performing ranging in coherent mode with a ground station in contingency mode (this requirement is verified by analysis and special test only).
01.05.01.07	F	Link Margin	Link margin shall be sufficient to support all phases of the mission.
01.05.01.07.01	P	Minimum Margin	A 3-dB margin shall be maintained in all phases of the mission.
01.05.01.08	F	Bit Error Rate (BER)	S-band end-to-end BER shall be less than 10E-7.
01.05.02	FC	X-Band Communication	X-band communications system shall provide downlink for science data.
01.05.02.01	F	Antenna	Shall accommodate electronically-steerable phased array antenna.
01.05.02.02	F	Ground Station	Shall transmit science data to a Wallops-managed ground station.
01.05.02.03	F	Frequency	Transmit frequency shall be per RF ICD.
01.05.02.04	F	Transmission Rate	Rate shall be sufficient to empty WARP recorder during one telemetry pass of 8-minutes duration.
01.05.02.04.01	P	Minimum Transmission	Transmission rate shall be 105 Mbps.
01.05.02.05	F	Format	X-band telemetry shall conform to CCSDS-recommended standards.
01.05.02.06	F	Downlink Protocol	Downlink protocol shall use CCSDS 701 AOS.
01.05.02.07	F	BER	X-band end-to-end BER shall be less than 10E-6.
01.06	H	Command and Data Handling (C&DH)	C&DH shall provide data processing, data storage, command and control, telemetry and timing for the EO-1 observatory.
01.06.01	FC	Command	C&DH shall process commands for execution aboard the observatory.
01.06.01.01	F	Commanding to Technologies	Shall provide sufficient commanding to support validation of the technologies.
01.06.01.02	F	Real-Time Commands	Shall provide real-time command ingest and execution.
01.06.01.03	F	Stored Commands	Shall provide stored command capability.

Requirement ID	Requirement Type	Requirement Title	Requirement Statement
01.06.01.04	F	Command Protocol	Shall conform to CCSDS COP-1 protocol.
01.06.02	FC	Telemetry	Shall be sufficient to support mission requirements.
01.06.02.01	F	Housekeeping Data	Shall collect sufficient housekeeping data from all technologies and spacecraft for operations, health and safety assessment, and technology validation.
01.06.02.02	F	Science Data Backup Path	Shall provide backup science data path via S-band.
01.06.02.03	F	Format	Shall conform to CCSDS AOS format.
01.06.03	FC	Wide Band Data Storage (WARP)	Shall provide adequate data storage for housekeeping and science data during mission.
01.06.03.01	F	Science Data	Shall provide science data storage capacity to allow validation of the ALI and AC technologies.
01.06.03.01.01	P	Scene Storage	Shall be capable of storing two full scenes, each not exceeding 20 Gb.
01.06.03.02	F	Housekeeping Data During Scene Taking	Shall be capable of storing housekeeping data during scene taking.
01.06.03.03	F	Data Ingest Rate	Shall provide sufficient ingest rate to capture all ALI, AC, and housekeeping data simultaneously.
01.06.03.03.01	P	Rate	TBD
01.06.03.04	F	Data Ingest Path	WARP shall be capable of ingesting ALI and AC data from either FODB or RS 422, selectable by command on-orbit.
01.06.03.05	F	Data Playback	WARP shall be capable of playback of science and housekeeping telemetry at 105 Mbps into the X-band phased array.
01.06.03.06	F	Backup Playback	Shall have backup playback capability at 4 Mbps (S-band).
01.06.04	FC	Housekeeping Data Storage	Shall have sufficient housekeeping data storage capacity.
01.06.04.01	F	Housekeeping Data Overflow	Overflow of housekeeping data shall be prohibited between nominal ground contacts.
01.06.04.01.01	P	Storage Capacity	Shall be capable of storing housekeeping data for 24 hours without overflow.
01.06.05	FC	Timing	Shall maintain and distribute time to sufficient accuracy to support the mission.
01.06.05.01	F	Technologies	Shall provide sufficient timekeeping to support technologies.
01.06.05.01.01	P	ALICE	Shall provide 10-ms accuracy to ALICE, with respect to UTC.
01.06.05.02	F	ACS	Shall provide sufficient timekeeping to support attitude determination and control.
01.06.05.03	F	Relative Accuracy	Observatory time shall be maintained to the required accuracy.
01.06.05.03.01	P	Onboard Accuracy	Time shall be maintained to within 1 mS between observatory components.
01.06.05.04	F	Ground Time Correlation	Observatory time shall be correlated to ground time with required accuracy.

Requirement ID	Requirement Type	Requirement Title	Requirement Statement
01.07	H	Propellant	Shall provide enough propellant to support the mission.
01.07.00.01	F	Fuel for Formation Flying	Fuel shall be sufficient to support Formation Flying with Landsat 7.
01.07.00.02	F	Fuel for Mission Ops & Disposal	Sufficient fuel shall remain at the end of the nominal mission plus extended operations to de-orbit within 25 years as dictated in NMI 1740.A.
01.08	H	Structure	The structure shall be sufficient to support validation of the technologies.
01.08.01	FC	Alignment	Shall determine alignment and make measurements.
01.08.01.01	F	Alignment Placement	Shall determine and maintain on-orbit alignment between instruments and ACS components during all phases of the mission.
01.08.01.02	F	Alignment Measurement	Shall make alignment measurements.
01.08.01.03	F	ALI and AC	ALI and AC instruments shall be co-aligned.
01.08.01.03.01	P	Alignment Accuracy	ALI and AC instruments shall be mounted to within 0.25° as listed in ICD.
01.08.01.03.02	P	Measurement Accuracy	ALI and AC instrument placement shall be measured to 30 arcsec with respect to the ACS reference.
01.08.01.04	F	Jitter Limiting	The design of the structure shall limit the jitter.
01.08.01.04.01	P	Jitter Budget	Shall be within the jitter allocation of the WIS 90% area rule error budget.
01.08.02	FC	Technology Mounting	Technology mounting on the spacecraft shall allow technology validation.
01.08.02.01	F	LFSA Mounting	Shall provide the mounting surface to allow deployment and sufficient view of the Sun to support validation.
01.08.02.02	F	CCR Mounting	Shall mount sufficient heat source in the vicinity of the CCR to allow heat conductivity validation.
01.08.02.03	F	PPT Mounting	Shall be mounted to allow pitch axis control.
01.09	H	Launch Vehicle	Shall be designed to accommodate launch vehicle.
01.09.00.01	F	Launch Vehicle Constraint	Shall be designed to launch as a top payload on the dual payload attach fitting on the Delta 7320 with 10-foot fairing.

Abbreviations and Acronyms

AC	Atmospheric Corrector
ACS	Attitude Control System
ALI	Advanced Land Imager
ALICE	
AOS	
arcsec	
BER	bit error rate
C&DH	command and data handling
CCR	Carbon-Carbon Radiator
CCSDS	Consultative Committee for Space Data Systems
COP	
dB	decibel
EO-1	Earth Orbiter-1
F	functional requirement
FC	functional category
FODB	Fiber Optic Data Bus
FPE	focal plane electronics
Gb	gigabit
H	hierarchical requirement
Hz	hertz
kbps	kilobits per second
km	kilometer
Krads	
LFSA	Lightweight, Flexible Solar Array
Mbps	megabits per second
MEV	
ms	millisecond
mS	

NMP	New Millennium Program
P	performance requirement
PPT	Pulsed Plasma Thruster
RF	radio frequency
SEE	
TBD	to be determined
TID	
UTC	universal time coordinated
WARP	Wideband Advanced Recorder/Processor
WIS	Wedge Imaging Spectrometer
XPAA	X-Band Phased Array Antenna